

UNITED STATES PATENT APPLICATION
FOR
PRE-FILLED CONTAINED MEDIA VOLUMES
AND
METHODS OF MEDIA FILLING USING PRE-FILLED CONTAINED MEDIA
VOLUMES
by
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I. CROSS-REFERENCE TO RELATED APPLICATION

[001] This application claims the benefit of U.S. Provisional Application No. 60/407,692, filed September 4, 2002, by Paul Teufel and titled PRE-FILLED CONTAINED MEDIA VOLUMES AND METHODS OF MEDIA FILLING USING PRE-FILLED CONTAINED MEDIA VOLUMES, the disclosure of which is expressly incorporated herein by reference.

II. BACKGROUND

A. Technical Field

[002] The present invention relates to pre-filled contained media volumes and methods of media filling using pre-filled contained media volumes. In particular, the present invention relates to apparatus and methods of media filling a tooling using pre-filled contained media volumes.

B. Related Art

[003] Presently, composite materials (such as fiber-reinforced plastics) are increasingly being used to manufacture aircraft. The manufacture of such aircraft includes the manufacture of the fuselage (the central body of the aircraft), the internal frames of the fuselage, and the various other components of the aircraft. Often the manufacture of an aircraft fuselage with composite materials includes the use of a tooling to form the shape of the fuselage. For example, in some manufacturing processes, laminate fibers are wrapped around a tooling, such as a mandrel, to form the fuselage.

[004] In certain applications, this tooling is constructed of elastomeric materials. The use of elastomeric materials provides for increased flexibility in the formation of the shape of the tooling. However, hollow elastomeric tooling

does not provide the rigidity often needed during the lay-up and curing process. Therefore, the elastomeric tooling can be filled with a granular media, such as ceramic spheres available under the product name Macrolite, metal balls or shot, metal filings, such as aluminum filings, thermoplastics or any other appropriate granular material, and held under vacuum to provide the necessary rigidity. After curing of the fuselage, the granular media is removed from the tooling, and the tooling is removed from the fuselage.

[005] In the course of filling the tooling with granular media, however, the granular media often does not flow to all interior volumes of the tooling. This may result in void pockets of air where granular media has not filled within the tooling. When the tooling is subsequently held under vacuum, the air in the void pockets of granular media dissipates causing the tooling in the area of the void pocket of granular media to be misshapen. This may lead to an improperly formed fuselage. Thus, there is a need for apparatus and methods for preventing air pockets from forming during media filling.

III. SUMMARY OF THE INVENTION

[006] Apparatus and methods consistent with the invention may provide for a method of filling a tooling with a granular media. The method includes filling a contained volume with a first granular media; attaching the contained volume in a portion of the tooling; and filling the tooling with a second granular media.

[007] Apparatus and methods consistent with the invention may also provide for a method of manufacturing a fuselage using a tooling. The method includes preparing the tooling; filling a contained volume with a first granular media; attaching the contained volume in a portion of the tooling; filling the

tooling with a second granular media; applying a curable resin to a fiber; applying the fiber over the tooling to form the fuselage; curing the fuselage; removing the media from the tooling; and extracting the tooling from the fuselage.

[008] Additional aspects of the invention are disclosed and defined by the appended claims. It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the invention as claimed.

IV. BRIEF DESCRIPTION OF THE DRAWINGS

[009] The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate several embodiments of the invention and, together with the following description, serve to explain the principles of the invention.

[010] In the drawings:

[011] Figure 1 is a perspective view of a fuselage for an aircraft;

[012] Figure 2 is a block diagram illustrating a process for creating a fuselage, as shown in Figure 1;

[013] Figure 3 is a block diagram illustrating the components of an internal tooling for manufacturing a fuselage consistent with an embodiment of the present invention, as shown in Figure 2;

[014] Figure 4 is a flow diagram illustrating creating a fuselage consistent with an embodiment of the invention, as shown in Figure 3;

[015] Figure 5 is a flow diagram illustrating a process for creating a fuselage using a mandrel tooling in accordance with one embodiment of the present invention, as shown in Figure 4;

[016] Figure 6A illustrates mandrel preparation consistent with an embodiment of the present invention, as shown in Figure 5;

[017] Figure 6B is a cut-away view of a portion of a mandrel consistent with an embodiment of the present invention, as shown in Figure 6A;

[018] Figure 7 is a perspective view of a mandrel in a form tool consistent with an embodiment of the present invention, as shown in Figure 6;

[019] Figure 8 illustrates introducing granular media into a mandrel consistent with an embodiment of the present invention, as shown in Figure 7;

[020] Figure 9A is a cut-away view of introducing granular media into a mandrel without a pre-filled contained media volume, as shown in Figure 8;

[021] Figure 9B is a cut-away view of a media-filled mandrel without a pre-filled contained media volume, as shown in Figure 9A;

[022] Figure 9C is a cut-away view of a mandrel with a pre-filled contained media volume consistent with an embodiment of the invention, as shown in Figure 8;

[023] Figure 9D is a cut-away view of a media-filled mandrel with a pre-filled contained media volume consistent with an embodiment of the present invention, as shown in Figure 9A;

[024] Figure 10 is a perspective view of a fuselage formed on a mandrel consistent with an embodiment of the invention, as shown in Figure 9D;

[025] Figure 11 illustrates removing granular media from a mandrel form consistent with an embodiment of the present invention, as shown in Figure 10;
and

[026] Figure 12 illustrates removing a mandrel from a mandrel form consistent with an embodiment of the present invention, as shown in Figures 11.

V. DESCRIPTION OF THE EMBODIMENTS

A. Introduction

[027] Apparatus and methods consistent with the present invention will now be described with respect to pre-filled contained media volumes and methods of media filling using pre-filled contained media volumes. The following examples are only representative of embodiments and implementations in accordance with the invention. Other embodiments and other implementations may also be used.

B. Apparatus and Methods

[028] Figure 1 is a perspective view of a fuselage for an aircraft. As shown in Figure 1, a fuselage 100 comprises a fuselage skin 140, frame sections 120, and attachment fittings 160 for wings. Fuselage 100 may also comprise other frame sections, attachments fittings, and flanges (not shown). Fuselage 100 may also comprise other components and subcomponents (not shown).

[029] Figure 2 is a block diagram illustrating a process for creating a fuselage, as shown in Figure 1. As shown in Figure 2, a process for creation of a fuselage 200 includes tooling 220, composite lay-up 230, and other 240. Tooling 220 includes any process utilizing tooling for manufacturing a fuselage. For example, tooling 220 may include the use of metal molds, molds made from composite materials, and/or mandrels made from metals and composite materials. Tooling 220 also includes the use of toolings made from elastomeric

materials such as silicone, urethane, latex, or natural rubbers. Tooling 220 further includes the use of such elements as plastic or metal dies and punches.

[030] Composite lay-up 230 includes the use of any appropriate composite material to form the skin of a fuselage. Composite lay-up 230 may include hand lay-up of composite plies, integration of tooling and lay-up, and filament winding, as well as other processes. Other 240 may include such processes as molding, integration of tooling and molding, and filament winding as well as other processes.

[031] Figure 3 is a block diagram illustrating the components of an internal tooling for manufacturing a fuselage consistent with an embodiment of the present invention, as shown in Figure 2. As shown in Figure 3, internal tooling 300 includes an elastomeric tooling for internal fuselage mandrel 320 made using apparatus and methods consistent with the present invention, granular media 330, and other 340. In this implementation, elastomeric tooling for internal fuselage mandrel 320 refers to an elastomeric bladder filled with granular media 330 to maintain the shape of a fuselage. Granular media 330 includes any appropriate granular material that will rigidize elastomeric tooling for internal fuselage mandrel 320 when a vacuum has been drawn on the tooling. In one implementation, granular media 330 comprises ceramic spheres available under the product name Macrolite. Granular media 330 may comprises other granular material, the elastomeric tooling can be filled with a granular media, such as metal balls or shot, metal filings, such as aluminum filings, thermoplastics or any other appropriate granular material. Other 340 may

include any other portions of the tooling. This implementation is merely exemplary, and other implementations may also be used.

[032] Figure 4 is a flow diagram illustrating creating a fuselage consistent with an embodiment of the invention, as shown in Figure 3. As shown in Figure 4, in one implementation, a process for creation of a fuselage 200 comprises internal tooling 300, composite lay-up 230, and external tooling 420. External tooling 420 includes the use of any appropriate tooling to shape the exterior of a fuselage. In one implementation, external tooling 420 includes the use of a circumferential external tool. As shown in Figure 4, in this implementation, the process for the creation of a fuselage 200 comprises the combination of internal tooling 300, composite lay-up 230, and external tooling 420, which results in fuselage 400. This implementation is merely exemplary, and other implementations may also be used.

[033] Figure 5 is a flow diagram illustrating a process for creating a fuselage using a mandrel tooling in accordance with one embodiment of the present invention, as shown in Figure 4. As shown in Figure 5, in one implementation, process 500 comprises start 510, prepare mandrel 520, form mandrel 530, fill with media 540, draw vacuum 545, place composite material 550, cure part 560, remove media 570, remove mandrel 580, and reuse 590.

[034] In this implementation, process 500 begins with start 510. After start 510 is prepare mandrel 520. In this implementation, prepare mandrel 520 comprises installation of the mandrel in a forming tool. In one implementation, the mandrel is an elastomeric bladder. In this implementation, the mandrel is

formed to approximate shape from pre-cured silicone material. Other materials, such as latex and nylon, may also be used. In another implementation, pre-filled media volumes, as described below, may be attached to the mandrel and may remain within the mandrel through all phases of process 500. Prepare mandrel 520 is further described in relation to Figures 6A-6B.

[035] In this implementation, prepare mandrel 520 is followed by form mandrel 530. Form mandrel 530 comprises the forming of the mandrel to the desired shape of the forming tool. Vacuum or pressure may be used to hold the proper shape of the elastomeric bladder prior to filling. Form mandrel 530 is further described in relation to Figure 7.

[036] In this implementation, form mandrel 530 is followed by fill with media 540. Fill with media 540 comprises filling the mandrel with granular media. In one implementation, fill with media 540 includes the use of gravity to fill the mandrel with granular media. Fill with media 540 may also comprise compacting the granular media. Fill with media 540 is further described in relation to Figures 8-9D.

[037] In this implementation, fill with media 540 is followed by draw vacuum 545. Draw vacuum 545 includes drawing a vacuum on the mandrel to rigidize the mandrel. Removing air and maintaining the media cavity under vacuum substantially rigidizes the mandrel for composite lay-up.

[038] In this implementation, draw vacuum 545 is followed by place composite material 550. Place composite material comprises the hand or

machine lay-up of laminate plies (prepreg or similar) onto the fuselage mandrel. Place composite material 550 is further described in relation to Figure 10.

[039] In this implementation, place composite material 550 is followed by cure part 560. Cure part 560 comprises the heating and pressurization of the composite materials to produce a structurally sound and lightweight fuselage. In one implementation, cure part 560 includes placing the part in a circumferential external mold. Cure part 560 is further illustrated in relation to Figure 10.

[040] In this implementation, cure part 560 is followed by remove media 570. Remove media 570 comprises the extraction of the granular media from the mandrel. Remove media 570 may also comprise dislodging any compacted granular media. Remove media 570 is further described in relation to Figure 11.

[041] In this implementation, remove media 570 is followed by remove mandrel 580. Removal mandrel 580 comprises the removal of the mandrel from the fuselage. Remove mandrel 580 is further described in relation to Figure 12. In one implementation, remove media 570 occurs prior to cure part 560.

[042] In this implementation, remove mandrel 580 is followed by reuse 590. As shown in Figure 5, after remove mandrel 580, reuse 590 indicates that the mandrel may be used again to form another fuselage.

[043] The stages in Figure 5 are merely exemplary, and other stages and other implementations may also be used.

[044] Figure 6A illustrates mandrel preparation consistent with an embodiment of the present invention, as shown in Figure 5. As shown in Figure 6A, an internal fuselage mandrel 600 may be used to form the internal shape of a

fuselage. In one implementation, internal fuselage mandrel 600 may comprise a bladder 610 and an armature 620. This implementation is merely exemplary, and other implementations may also be used.

[045] As shown in Figure 6A, bladder 610 creates the internal shape of the fuselage. In one implementation, bladder 610 may be a premolded silicone bag or mandrel 650, such as, for example, a reusable elastomeric mandrel currently available through International Design Technologies, Inc (IDT). Some silicone bag materials that have been found acceptable include those available from D Aircraft Products. In addition, there are other suppliers of high temperature (up to 400°F), unfilled, and uncured silicone sheet materials that may be used, depending upon the cure temperature of the desired part. Some of the other suppliers include Arlon, Mosite, and Kirkhill. These implementations are merely exemplary, and other implementations may also be used.

[046] Armature 620 is used to support bladder 610. In one implementation, a welded metal armature may be used. However, other materials could be used to form the armature. This implementation is merely exemplary, and other implementations may also be used.

[047] Figure 6B is a cut-away view of a portion of a mandrel consistent with an embodiment of the present invention, as shown in Figure 6A. As shown in Figure 6B, armature 620 may be inserted through bladder 610 to support bladder 610. To minimize weight and mandrel bending, armature 620 may be as large as possible, while allowing it to be removed from the bladder 610. As further shown in Figure 6B, inserting armature 620 in bladder 610 creates a

cavity 630. This implementation is merely exemplary, and other implementations may also be used.

[048] Figure 7 is a perspective view of a mandrel in a form tool consistent with an embodiment of the present invention, as shown in Figure 6. As shown in Figure 7, mandrel 600 is placed in a form tool 710 to form the desired shape of the fuselage. In one implementation, mandrel 600 is filled with air to force mandrel 600 to conform to the shape of the inner surface of form tool 710. In another implementation, a vacuum is used to hold mandrel 600 to the shape of form tool 710. These implementations are merely exemplary, and other implementations may also be used.

[049] Figure 8 illustrates introducing granular media into a mandrel consistent with an embodiment of the present invention, as shown in Figure 7. As shown in Figure 8, granular media 810 may be placed inside bladder 610 of mandrel 600 (as described above), which itself is contained within form tool 710. As shown in Figure 8, in one implementation, the introduction of granular media 810 is performed in a semi-horizontal orientation. However, in other implementations, other orientations, such as a vertical orientation or any other appropriate orientation, may be used for introducing granular media 810. These implementations are merely exemplary, and other implementations may also be used.

[050] Figure 9A is a cut-away view of introducing granular media into a mandrel without a pre-filled contained media volume, as shown in Figure 8. As shown in Figure 9A, in one implementation, granular media 810 is introduced into

cavity 630. Cavity 630 is located in the space between bladder 610 and armature 620. As shown in Figure 9A, bladder 610 is contained within form tool 710. As described above, if a vacuum has been applied to form tool 710, when granular media 810 is added, cavity 630 is vented to the atmosphere.

Alternatively, as described above, if pressure is applied to the interior of bladder 610, cavity 630 is filled with granular media 810 while pressurized. This implementation is merely exemplary, and other materials and implementations may also be used.

[051] As further shown in Figure 9A, in some instances, during media filling, granular media 810 may not flow to all parts of cavity 630. This failure to completely fill cavity 630 may leave a void pocket of media 910. Figure 9A shows one void pocket of media, however, multiple void pockets of media may be formed in any location in cavity 630. This implementation is merely exemplary, and other materials and implementations may also be used.

[052] Figure 9B is a cut-away view of a media-filled mandrel without a pre-filled contained media volume, as shown in Figure 9A. In one implementation, following introduction of granular media 810, a vacuum is applied to cavity 630 to rigidize the mandrel. As shown in Figure 9A, when the vacuum is applied to cavity 630, a section 920 of bladder 610 located by void pocket of media 910 (not shown in Figure 9B, but shown in Figure 9A) will be improperly formed. As shown in Figure 9B, in this implementation, section 920 may collapse inward. In this implementation, the tool must then be reformed to

create the desired shape. This implementation is merely exemplary, and other materials and implementations may also be used.

[053] Figure 9C is a cut-away view of a mandrel with a pre-filled contained media volume consistent with an embodiment of the invention, as shown in Figure 8. As shown in Figure 9C, in one implementation, a pre-filled contained media volume 930 may be attached to bladder 610 inside the media cavity 630 located between bladder 610 and armature 620. In one implementation, pre-filled contained media volume 930 is attached in an area likely to exhibit a media void. This implementation is merely exemplary, and other implementations may also be used.

[054] Pre-filled contained media volume 930 includes any container capable of holding granular media and allowing air to readily pass through. In one implementation, a porous fabric container filled with granular media forms a flexible pre-filled contained media volume 930. In another implementation, the porous fabric will be capable of withstanding the cure temperature typical in a composite part curing process. In one implementation in which cure temperature will be approximately 270 degrees Fahrenheit, the porous fabric may comprise fiberglass 7781 cloth weave commonly available from a variety of suppliers. Metallic screens or plastic films may also be used. These implementations are merely exemplary, and other materials and implementations may also be used.

[055] Pre-filled contained media volume 930 may have any appropriate size and shape to fill a desired portion of cavity 630. In one implementation, pre-filled contained media volume 930 may be as small as a small "bean bag" or as

large as a pillow, or approximately 1 in³ to 1ft³. In another implementation, pre-filled contained media volume 930 may be shaped to match the contours of the portion of cavity 630 in which it will be placed. In yet another implementation, pre-filled contained media volume 930 will conform to the shape of the portion of cavity 630 in which it will be placed upon filling cavity 630 with granular media. These implementations are merely exemplary, and other materials and implementations may also be used.

[056] In one embodiment, the granular media within the pre-filled contained media volume 930 is the same as the granular media introduced into cavity 630. However, in other embodiments different granular medias may be used in pre-filled contained media volume 930 and cavity 630. Because less granular media is needed to fill pre-filled contained media volume 930 a heavier or more expensive granular media with more desirable properties may be used in pre-filled contained media volume without substantial increases in cost or weight. These implementations are merely exemplary, and other materials and implementations may also be used.

[057] As described above, pre-filled contained media volume 930 may be attached to bladder 610 prior to filling bladder 610 with granular media. In one implementation, pre-filled contained media volume 930 will be attached using RTV silicone or a similar bonding agent. In another implementation, a plurality of pre-filled contained media volumes 930 may be attached to multiple points in bladder 610, which are likely to form media voids. These implementations are merely exemplary, and other materials and implementations may also be used.

[058] Figure 9D is a cut-away view of a media-filled mandrel with a pre-filled contained media volume consistent with an embodiment of the present invention, as shown in Figure 9A. As shown in Figure 9D, cavity 630 has been filled with granular media 810. In this implementation, a media void 910 (as shown in Figure 9A), will not form because pre-filled contained media volume 930 is filling the potential media void location. This implementation is merely exemplary, and other materials and implementations may also be used.

[059] As described in Figure 9B, in one implementation, following introduction of granular media 810, a vacuum is applied to cavity 630 to rigidize the mandrel. As shown in Figure 9D, in this implementation, when the vacuum is applied to cavity 630 comprising pre-filled contained media volume 930, section 920 of bladder 610 remains in the desired shape, unlike the implementation in Figure 9B. This implementation is merely exemplary, and other materials and implementations may also be used.

[060] Figure 10 is a perspective view of a fuselage formed on a mandrel consistent with an embodiment of the invention, as shown in Figure 9D. As shown in Figure 10, fuselage 1050 has been formed around fuselage mandrel 600. Any appropriate method may be used to form the fuselage. In one implementation, filament with resin is wound around fuselage mandrel 900 and then cured to form fuselage 1050. This implementation is merely exemplary, and other implementations may also be used.

[061] Figure 11 illustrates removing granular media from a mandrel form consistent with an embodiment of the present invention, as shown in Figure 10.

As shown in Figure 11, following the formation of fuselage 1050, granular media 810 (not shown) is removed from fuselage 1050. In one implementation, a vacuum 1120 removes granular media 810 through fill ports (not shown) in armature 620 (also not shown) in bladder 610. In other implementations, tilting and rotating of the tooling and/or the introduction of vibration or air pressure may be used to assist in the removal of the granular media. This implementation is merely exemplary, and other implementations may also be used.

[062] Figure 12 illustrates removing a mandrel from a mandrel form consistent with an embodiment of the present invention, as shown in Figures 11. As shown in Figure 11, following removal of the granular media and after the removal of armature 620 from fuselage 1050 (not shown), bladder 610 is also removed from fuselage 1050. These implementations are merely exemplary, and other implementations may also be used.

VI. CONCLUSION

[063] As described above, therefore, other embodiments of the invention will be apparent to those skilled in the art from consideration of the specification and practice of the invention disclosed herein. It is intended that the specification and examples be considered as exemplary only, with a true scope and spirit of the invention being indicated by the following claims and their equivalents. In this context, equivalents mean each and every implementation for carrying out the functions recited in the claims, even if not explicitly described therein.